PB80-200017

Pesticides: Their Impact on the Estuarine Environment

(U.S.) Environmental Research Lab.
Gulf Breeze, FL

1979

U.S. Department of Commerce
National Technical Information Service
NTIS

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2	3. RECIPIENT'S ACCESSION NO.
EPA-600/J-79-098	Journal Article	PB 80 200017

4. TITLE AND SUBTITLE
Pesticides: Their Impact On The Estuarine Environment

5. REPORT DATE

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)
DelWayne R. Nimmo

8. PERFORMING ORGANIZATION REPORT NO.

9. PERFORMING ORGANIZATION NAME AND ADDRESS

10. PROGRAM ELEMENT NO.

11. CONTRACT/GRANT NO.

12. SPONSORING AGENCY NAME AND ADDRESS
Environmental Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Gulf Breeze, FL 32561

13. TYPE OF REPORT AND PERIOD COVERED

14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES
Ref: Marine Pollution: Functional Responses pp. 259-270, 1979

16. ABSTRACT

Published research factors influencing the use of pesticides are discussed. One section reviews recent research on the effects of new pesticides that include insect growth regulators, including Permethrin^{R}, Altosid^{R}, and Dimilin^{R}. In life-cycle toxicity tests with the mysid Mysidopsis bahia, the 96-hr LC50 of Dimilin was 2.06 µg/l (95%) CL= 1.63 to 2.69 µg/l and and estimated concentration of 75 µg/l (parts per trillion) significantly reduced the number of young produced by each female mysid.
Author concludes: (1) more emphasis is needed on predicting or monitoring obvious potential sources of accidental estuarine contamination, as is being made possible by recent toxic substances legislation; (2) the ecological importance of non-point source of pesticides is documented from reports of effects observed on field populations of non-target animals exposed to a number of pesticides; (3) laboratory studies may underestimate the potential for environmental damage in the field.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pesticides Toxicology	Permethrin^{R} Altosid^{R} Dimilin^{R} Mysidopsis bahia	06/T 06/F

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES
Release to Public	Unclassified	
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

EPA-600/J-79-098
JOURNAL ARTICLE

PB80-200017

PESTICIDES: THEIR IMPACT ON THE ESTUARINE ENVIRONMENT

DelWayne R. Nimmo

U.S. Environmental Protection Agency
Environmental Research Laboratory
Sabine Island
Gulf Breeze, Florida

Synthetic organic pesticides have been present in our coastal waters for nearly four decades. The successful control of arthropods as vectors of disease by the pesticide, DDT, during and after World War II insured subsequent use of related chemicals and introduction into the environment. Only after the book, "Silent Spring" (Carson, 1962), was published did the general public become aware of the seemingly pervasive nature of some of these pesticides and their undesirable effects on non-target species or ecosystems. One year later, Butler and Springer (1963) described the potential hazards of pesticides to coastal areas in a paper entitled "Pesticides--A New Factor in Coastal Environments." The authors noted that earlier research (1945-1951) was concerned with species in inland waters, but more recent attention had been directed towards the effects of pesticides in coastal waters. Although the environmental awareness movement was in its infancy, usage of organic pesticides continued to increase throughout the 1960's. Toxicologists occasionally used marine species to test the effects of selected chemicals, but few addressed the potential ecological effects.

Not until the late 1960's was attention given to the pesticide problem generally and the impact on our coastal waters specifically. "Pesticides and the Living Landscape" (Rudd, 1964) directed attention to the potential ecological problems of pesticides. The book, "Since Silent Spring" (Graham, 1970), also addressed many related subjects, including a history of the Nation's response to the pesticide problem and the inadequate control of chemical pesticides other than DDT. However, in my opinion, the publication that inspired critical

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

examination of the effects of pesticides on the Nation's estuaries and marine waters was "DDT Residues in an East Coast Estuary: A Case of Biological Concentration of a Persistent Insecticide" (Woodwell *et al.*, 1967). As a result, this Nation was thrust into the 1970's "decade of environmental awareness," during which the use or misuse of pesticides became a prime concern.

FACTORS INFLUENCING THE USE OF PESTICIDES

Even with the environmental awareness of the 1970's, it is still difficult to determine the prime cause for the decline in use of DDT. Perhaps by looking at past annual-use trends, we can discover some of the reasons. Despite warnings of hazards during the early 1960's, production of chlorinated hydrocarbon pesticide types continued to increase by 6% per annum (von Rumker *et al.*, 1975). In 1969-70, some decreases in production were noted (probably entirely due to declining sales of DDT), but overall sales rebounded in the next two years, with at least 7% increase per year. Use of DDT actually began to decline as early as 1965 (von Rumker *et al.*, 1975), according to domestic sales receipts. Two factors could have operated in concert: public awareness of hazards of DDT or actions of the pesticide regulatory agencies.

Although restrictions by the Environmental Protection Agency (EPA) concerning the use of certain pesticides have been instituted, relatively few pesticide registrations have been cancelled (e.g., Kepone); most have been restricted to small-volume usage or to specialized locations or restricted uses, such as subsurface termite control. EPA's classification of chemicals in restricted or general-use categories, or its RPAR (rebuttal presumption against re-registration policy), gives notice to the manufacturers and the public that curtailment might follow. Chemicals must be registered before use is permitted and less than 100 new chemicals have received registration labels since 1972 (Betz, personal communication, Office of Pesticide Programs, EPA, Washington, D.C.). RPAR is a non-adversary process in which the evidence of risk or hazard versus the benefit of a chemical is accumulated over a period of months. The RPAR process is not supported by the chemical manufacturers (Anonymous; Farm Chemicals, 1977a) because the process presumes that the chemical is "harmful" and, therefore makes it necessary for the company to prove there is no potential for harmful effects, or that any risk can be minimized to an acceptable level. The risk/benefit assessment of RPAR may eventually decide in favor of the use of the chemical, but some manufacturers believe that RPAR can cause sales to

decrease because charges of risk or hazard (whether eventually founded or unfounded), often cast a cloud of doubt in the minds of the public about the propriety of using the chemical.

HOW THE PESTICIDE PROBLEM IS PERCEIVED

In national surveys of environmental problems, pesticides are ranked very high by some, but not necessarily all, elements of our society. For example, environmental problems in various freshwater streams in Texas were ranked by categories of pollutants (Hann, 1975) and pesticides were rated only ninth, preceded by such problems as pathogenic bacteria, organics, inorganic ions, nutrients, sediments, temperature changes, heavy metals, and radionuclides. On the other hand, at the conference where the above data were presented, Li (1975) showed that agricultural operations were responsible for 7.8% of the fish kills in the Nation's water from 1963-1972. Of the total fish killed, 37% occurred in estuarine water; of the fish killed by agricultural operations, 64.9% resulted from pesticides.

WHAT HAPPENS WHEN THE USE OF A PESTICIDE IS HALTED?

Abatement of pesticide use in or near an estuary does not guarantee that the effects of the pesticide already in the system will subside quickly. Historically, it has been difficult to document cases in which causal effects can be attributed to a specific pollutant, despite frequent circumstantial evidence. To validate possible effects, we have tended in the past to study chemicals that degrade slowly and, therefore, leave residues or metabolites.

In a recent publication, Klass and Belisle (1977) showed that after six years, DDT and metabolites in nine estuarine species were reduced from between 84 and 99%. DDE, a metabolite of DDT, was still present in 1973 but at reduced levels when compared to those in 1967. In contrast, Butler (in press) noted that total concentrations of DDT and metabolites from North Carolina fish did not decrease appreciably, but during the five-year study, there was a shift of DDT from 31 to 0% while DDE increased from 44 to 82%. The longevity of persistent chemicals in an estuary has been demonstrated in oysters monitored monthly for a polychlorinated biphenyl (PCB) in Escambia Bay, Florida (Wilson and Forester, 1978). PCB's in oysters showed definite decreases over time during the first four years (1969 to 1972), but the rate of decrease

diminished during the four succeeding years (1973 to mid-1976). Thus, concentration of certain persistent chemicals may diminish after curtailed usage, but rates of decline are evidently functions of rates of degradation or metabolism and rates of export out of estuaries. Unfortunately, in the case of pesticides, such as Kepone or DDT, the degradation rates can be extremely slow.

INCREASED HERBICIDE USAGE

From 1966 to 1971, the percentage increase in use of herbicides has surpassed that of other chemicals (von Rumker *et al.*, 1975) and many changes in agriculture and other markets forecast additional increases. Changing methods of agriculture, movement of people to areas offering more leisure activities out-of-doors, increased gardening, and newly constructed highways all contribute to increased reliance on herbicides. Increase in herbicide usage is also reflected in expenditures for expansion of airport runways, electric utilities, landscaping for large industrial sites, golf courses, etc.; in 1976, herbicides sales totaled an estimated $105 million on the retail market (Anonymous; Farm Chemicals, 1977b).

Increases in herbicide use could come from changes in agricultural practices. A new practice, "no-till or restricted-till" farming, consists of one crop planted with tilling, followed by a second planting without breaking and tilling the soil (Triplett and Van Doren, 1977). Instead of plowing under the previous cover crop, a special planter opens the soil by cutting through the mulch and plants the seed. Herbicides are applied before or during planting to control competing foliage. In comparison with conventional tillage, a saving results in labor, energy, moisture, and soil due to less erosion. Obviously, this practice increases reliance on chemical--herbicides to control the weeds and insecticides to control the increased populations of insects residing in the cover crop.

Present estimates indicate that about 90% of all herbicides used by the American farmer are applied to field crops: corn, 50%; soybeans, 17%; cotton, 11% (von Rumker *et al.*, 1975). Under typical conditions, less than an estimated 5% of the amount of the herbicides applied enter aquatic areas from run-off water (Unger and Bailey, 1977). These authors, however, presented data on two herbicides, dichlobenil and atrazine, that appear in surface runoff at concentrations as high as 7 and 11% of that applied, respectively.

In general, herbicides are considered less toxic to estuarine species than other pesticides and data supporting this

view were presented by Butler (1965). For example, he showed the organophorphorus-type insecticides to be about 1000 times more toxic than the herbicides to shrimp. We should be cautious, however, about generalizations because some herbicides are very toxic to aquatic organisms. For example, the herbicide trifluralin is acutely and chronically toxic to a freshwater daphnid and the fathead minnow at concentrations of a few parts per billion (µg/ℓ) (Macek *et al.*, 1976). Recently, Parrish *et al.* (in press) showed deleterious effects of trifluralin on reproduction of an estuarine fish (*Cyprinodon variegatus*) exposed to 1.3 µg/ℓ in a chronic test. The authors concluded that to protect this estuarine species throughout its reproductive phase, the maximum acceptable toxicant concentration (MATC) should be less than 1.3 µg/ℓ.

USE OF PESTICIDES IN INDUSTRY

Some chemicals, not generally recognized as pesticides, but produced in tremendous quantities for decades, could inflict more damage on the estuarine environment than many pesticides currently under study. For example, von Rumker *et al.* (1975) reported that in 1972, the annual production of creosote as a wood preservative was 970 million pounds; pentachlorophenol (PCP), 38 million pounds; and inorganic preservatives, 14.5 million pounds. Approximately 8% were used on marine pilings. PCP uses include treatment of railroad crossties and utility poles that may come in direct or indirect contact with water. Pentachlorophenol, as the sodium salt, is also used as a wide spectrum fungicide-bactericide to retard discoloration of freshly sawed lumber, and in the formulation of drilling lubricants for oil exploration (von Rumker *et al.*, 1975). One-third of the PCP sodium salt produced is used to inhibit algae and fungi in air-conditioning cooling towers. Small amounts of PCP are also used as a herbicide.

NEW PESTICIDES

The purpose of this section is to mention some of the new chemicals coming into use; a few are labeled for restricted use. Earlier I mentioned that the controlled use of pesticides can sometimes pose a minimal risk to the environment. The current problem to toxicologists, however, is the advent of new pesticides to replace those used historically. Most

of these are types of which we have little data as to their toxicity, bioconcentration, fate, or metabolism.

Among those likely to be used more widely in the future are the pyrethroids that are related to the naturally occurring insecticides, pyrethrins. The pyrethroids are more stable photochemically than pyrethrins because of their molecular structure, thereby retaining the features that give the molecule its insecticidal activity and low mammalian toxicity. One pyrethroid that shows promise of greater use is Permethrin® (Elliott, 1976). Its toxicity ratio of insect/rate was 1400, compared to that of another highly toxic insecticide, parathion, that had a ratio of only 11. Currently, at least three pyrethroid products are under pre-registration review by EPA.

The second group that appears to be a viable alternative to many insecticides currently in use is the insect growth regulators. This group contains two types that are distinguishable by their physiological action. Altosid®, also known as Methoprene, is an example of the juvenile-hormone type; Dimilin® is an example of a chemical that interferes with the molting process.

Altosid, a chemical analogue to a juvenile hormone of insects (Siddall, 1976), prevents the emergence of the adult from the pupal stage. A positive feature of the insecticide is that it needs to be present in the environment only during a critical life history stage of the target species. Absence of this chemical in the environment for weeks or months decreases chances of delayed toxicity to, or bioconcentration in, other species (e.g., fishes). Altosid is registered for flood-water mosquito control in non-crop areas and for certain uses on rice and pastures (Betz, personal communication, Office of Pesticide Programs, EPA, Washington, D.C.); registration labels are pending for other uses.

Another insect growth regulator (IGR), Dimilin, was approved by EPA only for control of the gypsy moth. It represents a group of chemicals that interfere with the formation of insect cuticle during molt, but whether this is the single mode of action is questioned (Wright, 1976). Wright observed that when reciprocal crosses of either males or females of the stable fly exposed to Dimilin mated with the opposite untreated sex, reduced fecundity and fertility resulted. Cunningham (1976) found similar results in mating pairs of brine shrimp, *Artemia salina*, after exposure to differing concentrations of Dimilin. Another possible concern with Dimilin and other insect growth regulators is their persistence. Metcalf *et al.* (1975) showed that they are moderately persistent in a laboratory model ecosystem, especially in killing invertebrates. Chironomid midges were effectively controlled in a California residential lake for 8-10 weeks after a single application of 0.1 pound per acre (Mulla *et al.*, 1976).

We have recently completed some life-cycle toxicity tests in which the mysid, *Mysidopsis bahia*, was exposed to Dimilin, using the methods of Nimmo *et al.* (1977). We determined survival of mysids and effects of the chemical on growth, reproduction and behavior in flowing water. The 96-hr LC50 was 2.06 µg/ℓ (95% confidence limits, 1.63-2.69 µg/ℓ). We also found that an estimated 75 ng/ℓ (parts-per-trillion) significantly reduced the number of young produced by each female mysid.

CONCLUSIONS

It is difficult to predict which pesticides will likely endanger coastal waters in the future. Judging from history, current or past contamination of estuaries by pesticides cannot be ascribed solely to agricultural uses or to the control of disease vectors. In many instances, pesticide pollution came inadvertently or mistakenly from point sources. Examples of accidental introduction are: (1) endrin in the Mississippi River in the early 1960's; (2) DDT released from the Los Angeles outfall into Pacific waters; and most recently (3) Kepone entering the James River in Virginia. We need to place more emphasis on predicting or monitoring obvious potential sources of accidental contamination. The recent toxic substances legislation will make this possible.

Some might infer that the non-point sources of pesticides should not be of major concern to ecologists. The argumentative scenario could be based on the following: (1) considering the successful control of hundreds of pests with hundreds of chemicals or formulations during the last four decades, estuarine environments have sustained imperceptible damage; or (2) the assimilative capacity of biological systems is greater than those often suggested. I counter these two notions with documented effects of pesticides on various biota after the chemicals had been applied in prescribed amounts (Table 1). These cases as summarized involve either (1) short-term physiological effects, such as depressed brain acetylcholinesterase activity in fishes after malathion was applied to estuarine waters in Louisiana, or (2) longer term effects, such as the development of pesticide-tolerant fish populations in Mississippi. Another example of a long-term effect is the well-known thinning of brown pelican eggshells that is directly associated with DDE (Blus *et al.*, 1972).

I also point out that laboratory studies, in some instances, may underestimate the potential for environmental damage in the field. In one instance, our laboratory studies on contamination in Escambia Bay, Florida, with three organisms

TABLE I. Summary of effects observed on field populations of animals after exposure to pesticides

Observed effects and organisms	*Pesticide*	*Reference*
Depressed acetylcholinesterase activity in brain tissue of fish	*Malathion*	*Coppage and Duke (1971)*
Failure of eggs to develop in seatrout	*DDT*	*Butler et al. (1970)*
Documenting the presence of pesticide-tolerant fish	*Strobane and Chlordane*	*Ferguson (1968)*
Failure to re-establish populations of bass	*Several*	*Bingham (1970)*
Eggshell thinning of brown pelican eggs	*DDE*	*Blus et al. (1972)*

underestimated the bioconcentration potential of the polychlorinated biphenyl (Aroclor® 1254) by one or two orders of magnitude below levels found in the tissues of the same three organisms captured from the Bay (Nimmo, 1976). The problem was also addressed by Livingston (1976), who noted that laboratory toxicity tests (particularly with the organochlorine pesticides) have not considered many contributing and synergistic factors present in the field; *e.g.*, reduced oxygen levels resulting in increased DDT toxicity to various freshwater fishes.

In the 1970's, investigators in the field of aquatic toxicology have discovered sophiscated, sensitive methods of determining effects of pesticides in various biota. Such advances include determinations of Kepone-induced pathology in fishes (Couch *et al.*, 1977), collagen/Vitamin C indicators of chronic organochlorine stress in fishes (Mehrle *et al.*, 1977), and routine use of life-cycle toxicity tests on fish (Parrish *et al.*, 1978) and a crustacean (Nimmo *et al.*, 1977). Determining the effects of a pesticide on the feeding activity of a polychaete is now an accepted test (Rubenstein, 1977). Procedures are also available to assess the movement of a pesticide through a laboratory food chain (Bahner *et al.*, 1977) and methods to determine impacts of toxicants on

communities of benthic organisms (Tagatz *et al.*, 1977) are now "standard" procedures. It is possible that a model of pesticide flux in a river and associated estuary will soon be announced. The future direction of research to meet the environmental challenges of new chemicals must be resolved by research groups from both academia and industry, as well as government. Whatever our role, forecasting the impact or safety of new chemicals, developing new methods to assess effects, or planning new research efforts--the increased use of such potentially harmful chemicals, as herbicides, wood preservatives, and second or third generation insecticides, should make us more alert as ecologists concerned with the environment.

ACKNOWLEDGMENTS

I thank Dr. Nelson R. Cooley for technical assistance on the manuscript. Gulf Breeze Contribution Number 366.

LITERATURE CITED

Anonymous, 1977a. A Trojan horse name RPAR. Farm Chemicals. 140(8): 13-20.

Anonymous, 1977b. Don't overlook the professional market. Farm Chemicals. 140(3): 56.

Bahner, L.H., A.J. Wilson, Jr., J.M. Sheppard, J.M. Patrick, Jr., L.R. Goodman, and G.E. Walsh. 1977. Kepone® bioconcentration, accumulation, loss, and transfer through estuarine food chains. Chesapeake Science 18: 299-308.

Bingham, C.R. 1970. Comparison of insecticide residues from two Mississippi oxbow lakes. Proc. 23rd Annu. Conf. Southeast. Assoc. Game and Fish Comm. Mobile, Ala. p. 275-280.

Blus, L.J., C.D. Gish, A.A. Belisle, and R.M. Prouty. 1972. Logarithmic relationship of DDE residues to eggshell thinning. Nature 235: 376-377.

Butler, P.A. 1965. Effects of herbicides on estuarine fauna. (Presented at the 18th Annual Meeting of the Southern Weed Conference, Jan. 19-21, Dallas, Texas) pp. 3.

Butler, P.A. 1977. Bioaccumulation of DDT and PCB in marine fishes. Second Symposium on Aquatic Toxicology ASTM, Cleveland, OH, Oct. 31-Nov. 1, 1977 (In Press).

Butler, P.A., R. Childress, and A.J. Wilson, Jr. 1970. The association of DDT residues with losses in marine productivity. *In* FAO Technical Conference on Marine Pollution and Its Effects on Living Resources and Fishing. Rome, Italy, FIR: MF/70/E-76. pp 1-13.

Butler, P.A., and P.F. Springer. 1963. Pesticides--a new factor in coastal environments. Trans. 28th N. M. Wildl. Nat. Resour. Conf. pp 378-390.

Carson, R.L. 1962. Silent Spring. Houghton Mifflin. Boston. pp. 368.

Coppage, D.L., and T.W. Duke. 1971. Effects of pesticides in estuaries along the Gulf and Southeast Atlantic Coasts. *In*: Proc. 2nd Gulf Coast Conf. Mosquito Suppression and Wildl. ,anag. New Orleans, LA. pp. 24-31.

Couch, J.A., J.T. Windstead, and L.R. Goodman. 1977. Kepone-induced scoliosis and its histological consequences in fish. Science 197:585-587.

Cunningham, P.A. 1976. Effects of dimilin (TH6040) on reproduction in the brine shrimp, *Artemia salina*. Environ. Entomol. 5: 701-706.

Elliott, M. 1976. Properties and applications of pyrethroids. Environ. Health Prospect. 14: 3-13.

Ferguson, D.E. 1968. Characteristics and significance of resistance to insecticides in fishes. Reservoir Fishery Resources Symposium. Athens, GA, pp. 531-536.

Graham, F., Jr. 1970. Since Silent Spring. Houghton Mifflin Co. Boston. pp. 332.

Hann, R.W. 1975. Industrial waste pollution and Gulf Coast estuaries. *In:* Fstuarine Pollution Control and Assessment 1: 319-329. Office of Water Planning and Standards, EPA, Washington, DC.

Klass, E.E. and A.A. Belisle. 1977. Organochlorine pesticide and polychlorinated bephenyl residues in selected fauna from a New Jersey salt marsh--1967 vs. 1973. Pest. Monit. J. 10: 149-158.

Li, M. 1975. Pollution in nation's estuaries originating from the agricultural use of pesticides. *In*: Estuarine Pollution Control and Assessment 2: 451-466. Office of Water Planning and Standards, EPA, Washington, DC.

Livingston, R.J. 1976. Dynamics of organochlorine pesticides in estuarine systems: effects on estuarine biota. Estuarine Processes 1: 507-522.

Macek, K.J., M.A. Lindberg, S. Sauter, K.S. Buxton, and P.A. Costa. 1976. Toxicity of four pesticides to water fleas and fathead minnows. EPA-600/3-76-099 pp. 57. U.S. Environmental Protection Agency., Washington, D.C.

Mehrle, D.M., F.L. Mayer, and W.W. Johnson. 1977. Diet quality in fish toxicology: effects on acute and chronic

toxicity. *In*: Aquatic Toxicology and Hazard Evaluation, ASTM **STP 634**. F.L. Mayer and J.L. Hamelink, eds. American Society for Testing and Materials.

Metcalf, R.L., P. Lu, and S. Bowlus. 1975. Degradation and environmental fate of 1-(2,6-difluorbenzoyl)-3-(4-chlorophenyl) area. J. Agric. Food Chem. 23: 359-364.

Mulla, M.S., W.L. Kramer, and D.R. Barnard. 1976. Insect growth regulators for control of chironomid midges in residential-recreational lakes. Jour. Econ. Entomol. 69: 285-291.

Nimmo, D.R. 1976. Statement before the Committee on Merchant Marine and Fisheries, House of Representatives, on the matter of Polychlorinated Biphenyls, Jan. 28, 29, 30, 1976. Serial No. 94-24: 138-166.

Nimmo, D.R., L.H. Bahner, R.A. Rigby, J.M. Sheppard, and A.J. Wilson, Jr. 1977. *Mysidopsis bahia:* an estuarine species suitable for life-cycle toxicity test to determine the effects of a pollutant. Aquatic Toxicology Hazard Evaluation, STM STP 634. F.L. Mayer and J.L. Hamelink, eds., American Society for Testing Materials.

Parrish, P.R., E.E. Dyar, J.M. Enos, and W.G. Wilson. 1978. Chronic toxicity of chlordane, trifluralin, and pentachlorophenol to sheepshead minnows (*Cyprinodon variegatus*). EPA-60D/3-78-010 pp. 53. U.S. Environmental Protection Agency, Washington, D.C.

Rubinstein, N.I. 1978. Effect of sodium pentachlorophenate on the feeding acitivity of the lugworm, *Arenicola cristata* Stimpson. *In:* Pentachlorophenol: Chemistry, Pharmacology and Environmental Toxicology. K.R. Rao, ed., Plenum Press. New York and London. pp. 175-179.

Rudd, R.L. 1964. Pesticides and the Living Landscape. Univ. Wisconsin Press, Madison WI. pp. 320.

Siddall, J.B. 1976. Insect growth regulators and insect control: a critical appraisal. Environ. Health Prospect. 14: 119-126.

Tagatz, M.E., J.M. Ivey, J.C. Moore, and M. Tobia. 1977. Effects of pentachlorophenol on the development of estuarine communities. J. Toxicol. Environ. Health 3: 501-506.

Triplett, G.B., Jr., and D.M. Van Doren, Jr., 1977. Agriculture without tillage. Scientific American 236: 28-33.

Unger, S.G., and G.W. Bailey. 1977. Environmental implications of trends in agriculture and silviculture. Vol. 1: Trend identification and evaluation. Ecological Research Series EPA-600/3-77-121.

von Rumker, R., E.W. Lawless, and A.F. Meiners. 1975. Production, distribution, use and environmental impact potential of selected pesticides. EPA 540/1-74-001. U.S. Environmental Protection Agency, Washington, D.C.

Wilson, A.J. and J. Forester. 1978. Persistence of Aroclor 1254 in a contaminated estuary. Bull. Environ. Contam. Toxicol. 19: 637-640.

Woodwell, G.M., C.F. Wurster, Jr., and P.A. Isaacson. 1967. DDT residues in an east coast estuary: a case of biological concentration of a persistent insecticide. Science: 156: 822-823.

Wright, J.E. 1976. Environmental and toxicological aspects of insect growth regulators. Environ. Health Prospect. 14: 127-132.

PRINTED IN U.S.A.